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Integrating IAEA's Physical Model with JRC's The Big Table document search tool

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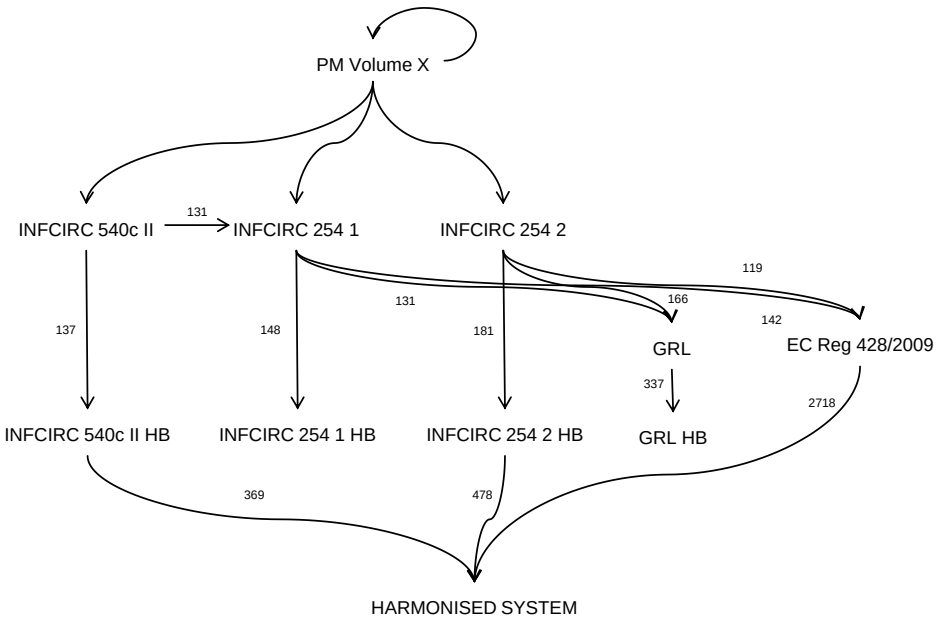

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0. Abstract

The Physical Model (PM) is an internal multi-Volume document for the IAEA's Department of Safeguards describing the nuclear fuel cycle. This report describes work carried out by the JRC with the IAEA to prototype the integration of the PM with The Big Table (TBT), a document search tool developed by the JRC and in use at the IAEA.

The core of TBT is an integrated collection of reference documents including regulatory documents, technical handbooks and trade nomenclatures. The documents are stored in a database. They are searchable by text in a structured way (i.e. on database fields) and also by correspondence tables that relate items by their meaning.

To integrate the Physical Model into TBT, the IAEA/SG/SGIM has first turned the PM into a tabular format. JRC has then proposed and implemented a way of coding the PM in TBT tables to better reflect the PM structure. Eleven PM Volumes have been integrated in a TBT-PM database for use by the IAEA. The PM Volumes are linked by correspondence tables to other documents in the TBT collection.

By coding the Physical Model into a TBT database format, the original intended uses of the PM are still supported. TBT can ease the consultation of the PM for evaluating States' nuclear activities by IAEA's analysts. TBT can be an aid for IAEA's inspectors preparing for routine and ad hoc inspections, design information verification visits and complementary access operations. Further the PM integrated into TBT can be used as a tool for training inspectors on steps of the nuclear fuel cycle.

Finally implementing the Physical Model multi-level structure into a database-coded format opens the possibility of linking the PM to other taxonomies and collections of open sources relevant for safeguards analyses.

1. Introduction

This report describes work carried out to integrate the IAEA's Physical Model (PM) [1] into JRC's The Big Table (TBT) [2] tool both of which are in use at the IAEA. The specific objective of the work is twofold:

- To make the Physical Model documents searchable in a structured way by storing them in a database format.
- To link the Physical Model to other documents to which the PM either makes explicit reference (e.g., the Additional Protocol [3], the Nuclear Suppliers Group (NSG) guidelines for export controls [4][5]) or to which the PM is related by means of the technical items it refers to (e.g., technical handbooks, the Harmonized System trade nomenclature).

By turning the Physical Model into a database format compatible with The Big Table, the original intended uses of the PM [1] are supported:

- TBT can ease the consultation of the PM for evaluating States' nuclear activities by IAEA's analysts.
- TBT can be an aid for IAEA's inspectors preparing for routine and ad hoc inspections, design information verification and complementary access.

Further the PM integrated into TBT can be used as a tool for training inspectors on steps of the nuclear fuel cycle.

Finally implementing the Physical Model multi-level structure (see Section 2) into a database-coded format opens the possibility of linking the PM to other taxonomies and collections of open sources relevant to safeguards analyses. For example:

- Global trade data [6] about States' imports and exports –indexed by Harmonized System (HS) [7] taxonomy of goods by the World Customs Organisation (WCO).
- The Kompass [8] business-to-business directory of companies and industries – organized by a proprietary taxonomy.
- The Inspec [9] database of scientific literature in the fields of physics and engineering –ordered by a proprietary classification system.

Creating correspondences between the PM structure and the above taxonomies enables the systematic retrieval of data on trade, industrial infrastructure and scientific research, having these data organized by the PM reference framework. The PM-TBT integration work is also functional to this goal.

The remainder of the report is organised as follows. Section 2 overviews the Physical Model structure and building blocks. Section 3 introduces The Big Table, its document collection and document search modalities. Section 4 presents how the Physical Model documents were integrated into The Big Table collection. Section 5 reports on open issues and suggests future work.

2. The Physical Model

The Physical Model is a set of documents[1] created to be used by the IAEA, Department of Safeguards as a tool during their evaluation of nuclear-related information for a State. [1].

Hereafter we recall the PM multi-level structure and its building blocks for this report to be self-contained.

- The PM describes the top-level technologies and the processes underlying the Nuclear Fuel Cycle.
- *Technologies* correspond to steps of the nuclear fuel cycle (Figure 1). They are described in dedicated Volumes (Table 1) written by expert groups along a common structure. Volumes are dated 1999 or later. Some Volumes have been revised over time. Others[2] are under revision.
- A PM Volume characterises all possible *processes* underlying a given technology. Processes are described at different level of abstraction. For example, Figure 2 shows two-level processes for acquiring enriched uranium.
- Processes are detailed in *narratives* (or *basic elements*) under the Headings reported in Table 2. Besides the general process description (Heading A), several *items* may be detailed under Headings B, C, … to J, as required. For example, under narrative C on dual-use equipment, several items are listed and described for the gas centrifuge enrichment process of uranium hexafluoride. Generally items are highlighted in Volumes as distinct Subheadings under each narrative, with some exceptions[3].
- The PM characterizes technologies and processes in terms of *indicators* which specify the existence or development of specific technologies or processes. The specificity of an indicator for a given technology or process determines its *strength* as strong, medium or weak (and sometimes less than weak). Indicators are listed both in explicit relationship to items (i.e., in the narrative text in the main Volume body) and also at the end of each Volume in *indicators tables* capturing all indicators relevant to a given technology or process. An ANNEX to the PM lists all indicators for the complete set of PM Volumes (Table 1).
- In listing equipment, materials and techniques associated with nuclear activities, the PM makes reference to:
    - *Especially designed equipment and materials* listed in the Additional Protocol Annex II [3] and in the NSG guidelines Part 1 [4].
    - *Dual-use equipment and materials* listed in the NSG guidelines Part 2 [5].

  References to the NSG exist in several PM Volumes (Table 1): Volume 2 (Conversion 1 and 2), 3 (Enrichment of Uranium), 5 (Fuel Fabrication), 6 (Nuclear Reactors), 7 (Deuterium/Heavy Water Production), and 8 (Reprocessing of Irradiated Fuel).

Figure 3 depicts the hierarchical structure of a Volume in the Physical Model. Note that narrative parts can be attached to each process level or just the bottom one (as in Volume 3 on Enrichment). Narratives are present at all process levels in the indicators tables at the end of each Volume (Figure 4).

[1] Access to the Physical Model document is limited to IAEA's Department of Safeguards.
[2] At the time of this writing: Volume 3 (Enrichment of Uranium), 7 (Deuterium/Heavy Water Production), and 8 (Reprocessing of Irradiated Fuel).
[3] For example, in Volume 8 on the Reprocessing of Irradiated Fuel, items are in many cases just highlighted in bold and embedded in paragraphs.

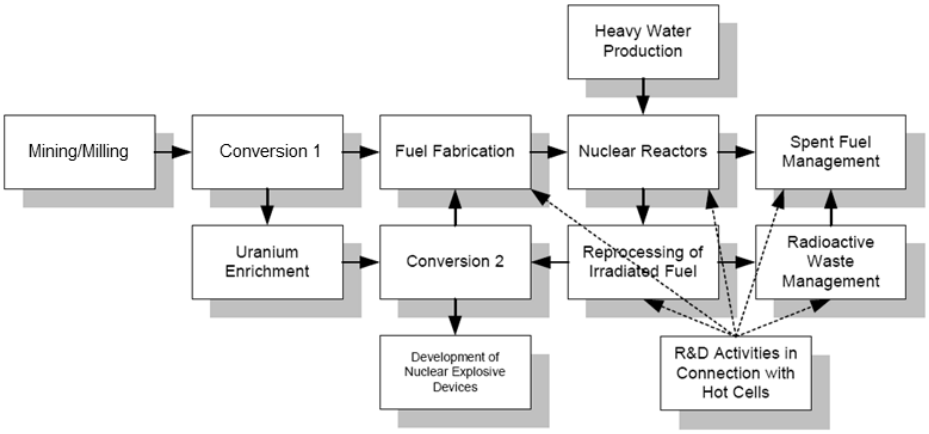

Figure 1 – The Physical Model Acquisition Path. Figure as in [1].

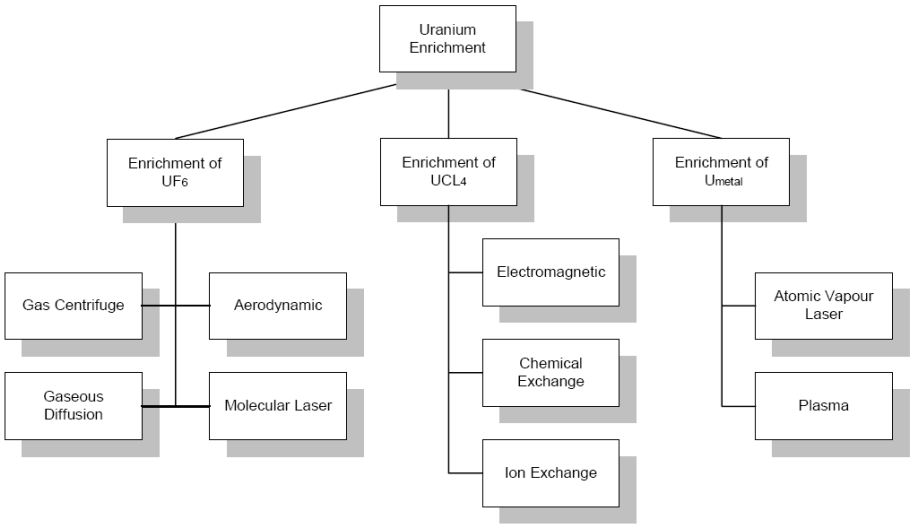

Figure 2 – Possible processes underlying the Acquisition Path for enriched uranium. Figure as in [1].

Volume	Title	Date	Nr. pages	References
1	Mining & Milling	1999 May	51	-
2	Conversion 1 and 2	2010 April	182	• NSG 2
3	Enrichment of Uranium	2008 Jan	222	• AP • NSG 2
4	[No longer exists as independent Volume. It was merged with Volume 2.]			
5	Fuel Fabrication	1999 May	30	• NSG 1
6	Nuclear Reactors	1999 May	108	• NSG 1 • NSG 2
7	Deuterium/Heavy Water Production	1999 May	24	• NSG 1
8	Reprocessing of Irradiated Fuel	2004 Mar	109	• NSG 1 • NSG 2
9	Spent Fuel Management	2000 Nov	42	-
10	Radioactive Waste Management	2002 Oct	107	-
11	Hot Cell Operations at Nuclear R&D Centers	2002 Jan	99	-
12	Development of Nuclear Explosive Devices	-	-	-
ANNEX	List of Indicators	1999 May	28	• NSG 1 • NSG 2

Table 1 – Volumes of the Physical Model.

Narrative ID	Narrative Title
A	General process description
B	Especially designed equipment
C	Dual-use equipment
D	Non-nuclear materials
E	Nuclear materials
F	Technology / training / R&D
G	Other observables
H	By-products/effluents
I	End products
J	Proliferation aspects

Table 2 – Narratives Headings used in the Physical Model to describe processes.

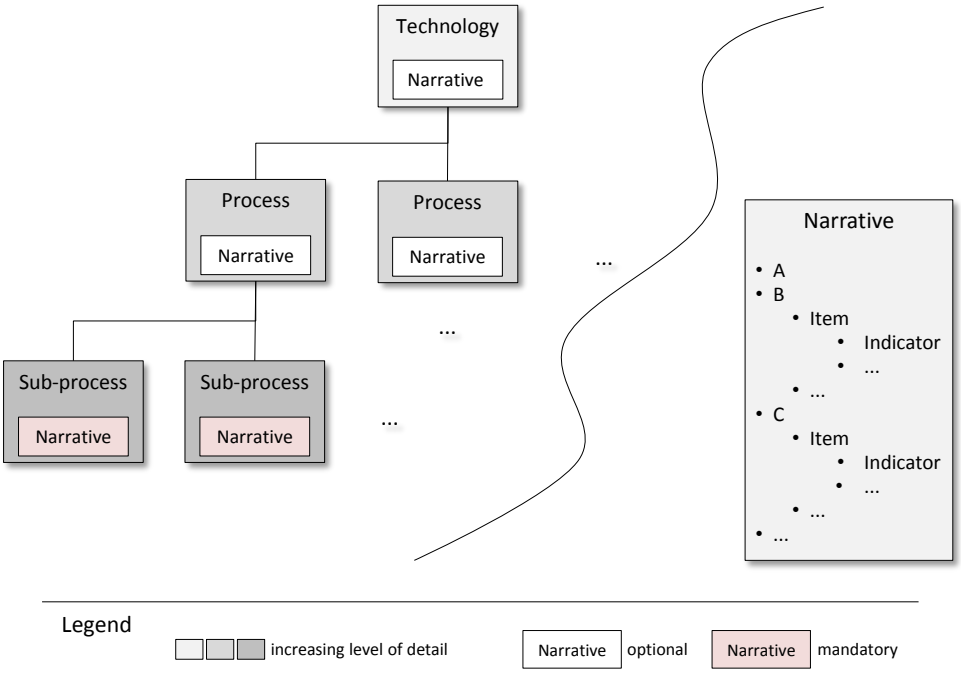

Figure 3 – Structure of a Physical Model Volume main body text.

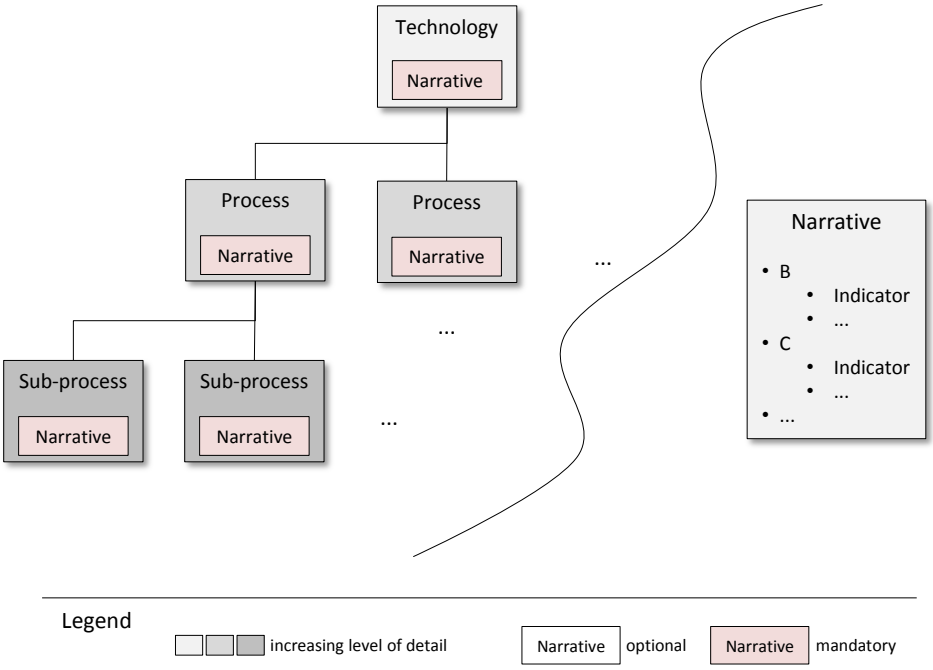

Figure 4 – Structure of a Physical Model table of indicators.

3. The Big Table

The Big Table [2] is a tool designed to search a collection of reference documents for IAEA's safeguards and export control of dual-use items[4]. In this domain the TBT document collection is on regulatory documents, technical handbooks and the Harmonized System [7] taxonomy of goods. Documents can be searched either by text or by correspondence tables on related items listed in different documents as explained in this Section.

3.1. The document collection

TBT's document collection (Table 3) includes documents on areas of export controls –at present the nuclear, missile, chemical and biological areas. In the 'general' cross-cutting area we find, besides the Harmonized System [7], the European Union Regulation for export controls EC Reg 428/2009 [10]. Hereafter we shortly describe the documents in the nuclear and general areas that will be related to the Physical Model.

- *INFCIRC 540c Annex II* of the Additional Protocol (AP) [3] lists especially designed or prepared equipment (single-use) and non-nuclear material for the reporting to the IAEA of exports under AP. This list of items is based on the 1995 version of the 'Trigger List' set originally by the Zangger Committee and adopted by the NSG. *INFCIRC 540c Annex II HB* [11] is a handbook developed for IAEA on items in AP Annex II. It expands the definitions given in [3], describes the items' appearance as manufactured or packaged, and lists HS codes applicable to the items.
- The IAEA publishes as *INFCIRC 254 1* the NSG 'Guidelines for the Export of Nuclear Material, Equipment and Technology' [4] (referred to as NSG Part 1 or the Trigger List) and as *INFCIRC 254 2* the NSG 'Guidelines for Transfers of Nuclear-related Dual-use Equipment, Materials, Software and Related Technology' [5] (NSG Part 2). INFCIRC 254 1 lists especially designed or prepared equipment and related non-nuclear materials. In INFCIRC 254 2, 'dual-use' items means items that have nuclear and non-nuclear applications. Both lists are updated by the NSG over time to cope with evolving nuclear technologies. *INFCIRC 254 1 HB* [12] and *INFCIRC 254 2 HB* [13] are handbooks developed on the NSG lists of items. The documents are organised by the original NSG lists. An NSG item's definition is expanded by an introductory note, a description of the appearance of the item as manufactured or packaged (including images), health and safety cautions associated with the item, and its typical nuclear and non-nuclear uses. INFCIRC 254 2 HB also indicates some Harmonized System codes (see below) that may be used by traders to declare export of these items to customs authorities.
- In 1991 Annex 3 of the IAEA's Ongoing Monitoring and Verification established a list of nuclear and nuclear-related items whose export was either prohibited to Iraq or subject to controls. The list, referred as Iraq Goods Review List (GRL) or *GRL Annex III* [14], includes both single-use items (i.e., especially designed or prepared for the processing, use or production of special fissionable material) as well as dual-use items. *GRL Annex III HB* [15] is the associated handbook: items' definitions are expanded by an introductory note, a description of the typical appearance of the item, health and safety cautions associated with it, typical nuclear uses, and site-specific photos taken by IAEA inspection teams in Iraq. This list includes items that have been removed from NSG export controls lists because they have become too common to be controlled. In specific cases these can still be used as indicators of activities of interest to safeguards.
- The European Union *EC Reg 428/2009 Annex I* [10] and amendments [16][17] combines several internationally agreed export controls lists including those published by the Wassenaar Arrangement (WA) [18], the Missile Technology Control Regime (MTCR) [19], the Nuclear Suppliers' Group (NSG) [20], the Australia Group (AG) [21] and the Chemical Weapons Convention (CWC) [22]. The Regulation provides a single list of items and technologies drawn from the individual export controls lists, including the NSG Guidelines, Part 1 and Part 2. Besides EC Reg 428/2009, other Regulations restrict the export of specific items to given destinations to implement resolutions by the United Nations Security Council. This is the case with the Council Regulation on restrictive measures against Iran EC Reg

[4] Items that have both civilian and military applications.

423/2007 [23] and amendments, including Regulation 961/2010 [24]. Another example is the Regulation on restrictive measures against the Democratic People's Republic of Korea, first published as EC Reg 329/2007 [25], amended by EC Reg 567/2010 [26].

- The *Harmonized System* (HS) [7] is the reference taxonomy for commodities adopted by customs adhering to World Customs Organisation (WCO), trade associations and statistical offices in the majority of countries. HS is based on about 5,000 commodity groups organized within 22 Sections in a hierarchy made up of: Chapters, Headings, and Subheadings. Each level in the hierarchy is identified by an *HS code* and an *HS explanatory note*. Codes are 2-digit for Chapters, 4-digit for Headings and 6-digit for Subheadings. The HS is used by importers and exporters to declare goods to customs authorities in all countries members to the WCO.

Area	**Document**	**Access**	**TBT records**
General	EC Reg 428/2009 Annex I (2009)	Public	2218
	Harmonized System (2002)	Public	6258
Nuclear	INFCIRC 540c Annexes I, II (1997)	Public	154
	INFCIRC 540 HB Annex II (2004)	IAEA	137
	INFCIRC 254 1 rev10 (2011)	Public	158
	INFCIRC 254 1 HB (2002)	NSG	148
	INFCIRC 254 2 rev8 (2010)	Public	230
	INFCIRC 254 2 HB (2003)	NSG	181
	GRL Annex 3 (2002)	Public	415
	GRL HB Annex 3 (1998)	IAEA	391
	EC Reg 961/2010 Annexes II, IV (2010)	Public	81
	EC Reg 567/2010 Annex I (2010)	Public	83
Missile	MTCR Annex (2011)	Public	399
	MTCR HB (2010)	Public	398
Chemical, Biological	AG CWP (2009)	Public	63
	AG CWP HB (2005)	AG	63
	AG DU CHEM (2011)	Public	98
	AG DU CHEM HB (2007)	AG	92
	AG DU BIO (2009)	Public	18
	AG DU BIO HB (2010)	AG	16
	AG BIO AGE (2011)	Public	86
	AG PLANT PAT (2011)	Public	19
	AG ANIMAL PAT (2011)	Public	24

Table 3 – The Big Table document collection as of June 2012.

3.2. Searching the document collection

The TBT document collection is stored in a database. There is a *database table per document*. Records in the document table identify items listed and described in the specific document. An item's record is made of the following fields:

- *Code*: alpha-numeric identifier of the item, as per native document (mandatory, primary key in the database table);
- *Title*: as per native document (mandatory);
- *Description*: as per native document (optional);
- *Note*: as per native document (optional); and
- *User note*; annotation as specified by a TBT user (optional).

The *Code* of an item is best chosen when it reflects the multi-level structure of the native document. This can be verified by showing the document tree in the *Context* Tab of the TBT interface. TBT builds the tree based on the *Codes* hierarchy and displays the *Titles* next to them as illustrated in Figure 5 for the INFCIRC 254 1 document.

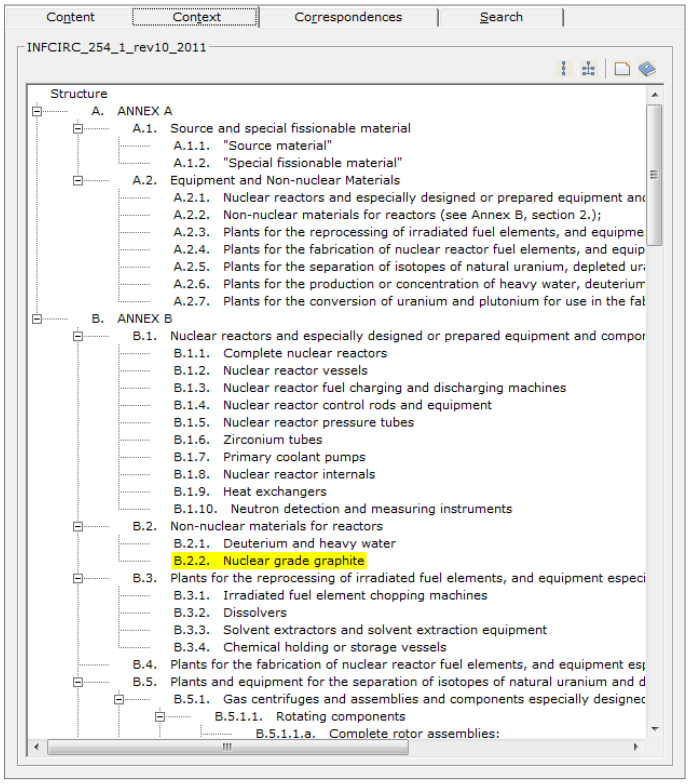

Figure 5 – Document tree as displayed in TBT's *Context* Tab.

Having documents set in this format allows searching the TBT collection by text in a structured way by restricting the fields of the search (e.g., search only on *Title*, or search only on *Description*). Compared to a full text search this approach leads to more precise results returned. A full text search is still possible by searching on all fields simultaneously.

Beyond the document tables, the TBT database includes *correspondence tables* between related items appearing in pairs of documents. Items are linked by their *Code* in a relationship that can be many-to-many. Table 4 shows how documents are linked by correspondence tables in the 'general' and 'nuclear' areas of the TBT document collection.

Correspondence tables extend the way the document collection can be searched. They enable relating items by their meaning rather than by equal text. For example, 'Nuclear grade graphite' can be related to 'Parts of nuclear reactors' even if the word 'graphite' does not appear there.

In TBT correspondence tables are of two types:

- *Native* when they are made by experts who identified related items listed in pairs of documents on a case-by-case basis.
- *Derived* when they are obtained by *joining existing correspondence tables* (native or derived). The derivation of correspondences is semi-automatic. To derive a new correspondence, an expert needs to indicate which existing correspondences are to

be joined for TBT, and in which sequence. A good use of this correspondence derivation mechanism allows creating a dense network of meaningful links in the document collection as shown in Table 4, where half of the correspondences are derived.

Correspondences • n: native • d: derived	EC Reg 428/2009	Harmonized System	INFCIRC 540c	INFCIRC 540 HB	INFCIRC 254 1	INFCIRC 254 1 HB	INFCIRC 254 2	INFCIRC 254 2 HB	GRL	GRL HB	EC Reg 961/2010	EC Reg 567/2010
EC Reg 428/2009		n	d	d	n	d	n	d	d	d	n	n
Harmonized System	n		d	n	d	d	d	n	d	d	n	n
INFCIRC 540c	d	d	n	n	n	d	n		n	d		
INFCIRC 540 HB	d	n	n		d				d			
INFCIRC 254 1	n	d	n	d		n			n	d		
INFCIRC 254 1 HB	d	d	d		n				d			
INFCIRC 254 2	n	d	n					n	n	d		
INFCIRC 254 2 HB	d	n					n		d			
GRL	d	d	n	d	n	d	n	d		n		
GRL HB	d	d	d		d		d		n			
EC Reg 961/2010	n	n										n
EC Reg 567/2010	n	n									n	

Table 4 – Correspondence tables implemented in TBT within the general and nuclear areas: n are native correspondences, d are derived correspondences.

Figure 6 illustrates TBT's search interface. In this example the document INFCIRC 254 1 is taken as Focus document and searched on 'graphite' in the *Title* field. There is only one matching record returned[5], i.e. item 'B.2.2 Nuclear grade graphite'. The corresponding PDF page is loaded on a *Viewer* so that the user can read the selected result directly in the original document and not only as a database record. As complementary information, the *Tab of correspondences* shows items related to the result, but listed in other documents of the collection. These items can be selected and viewed as database records or PDF pages. For example, Figure 6 shows a list of three Harmonized System codes linked to'B.2.2 Nuclear grade graphite', including '8401.40. Parts of nuclear reactors, n.e.s. [Euratom]'. Also, the *Tab of correspondences* indicates that there are records related to 'graphite' in Volume 6 of the Physical Model on Nuclear reactors.

[5] A full text search would return 11 records instead.

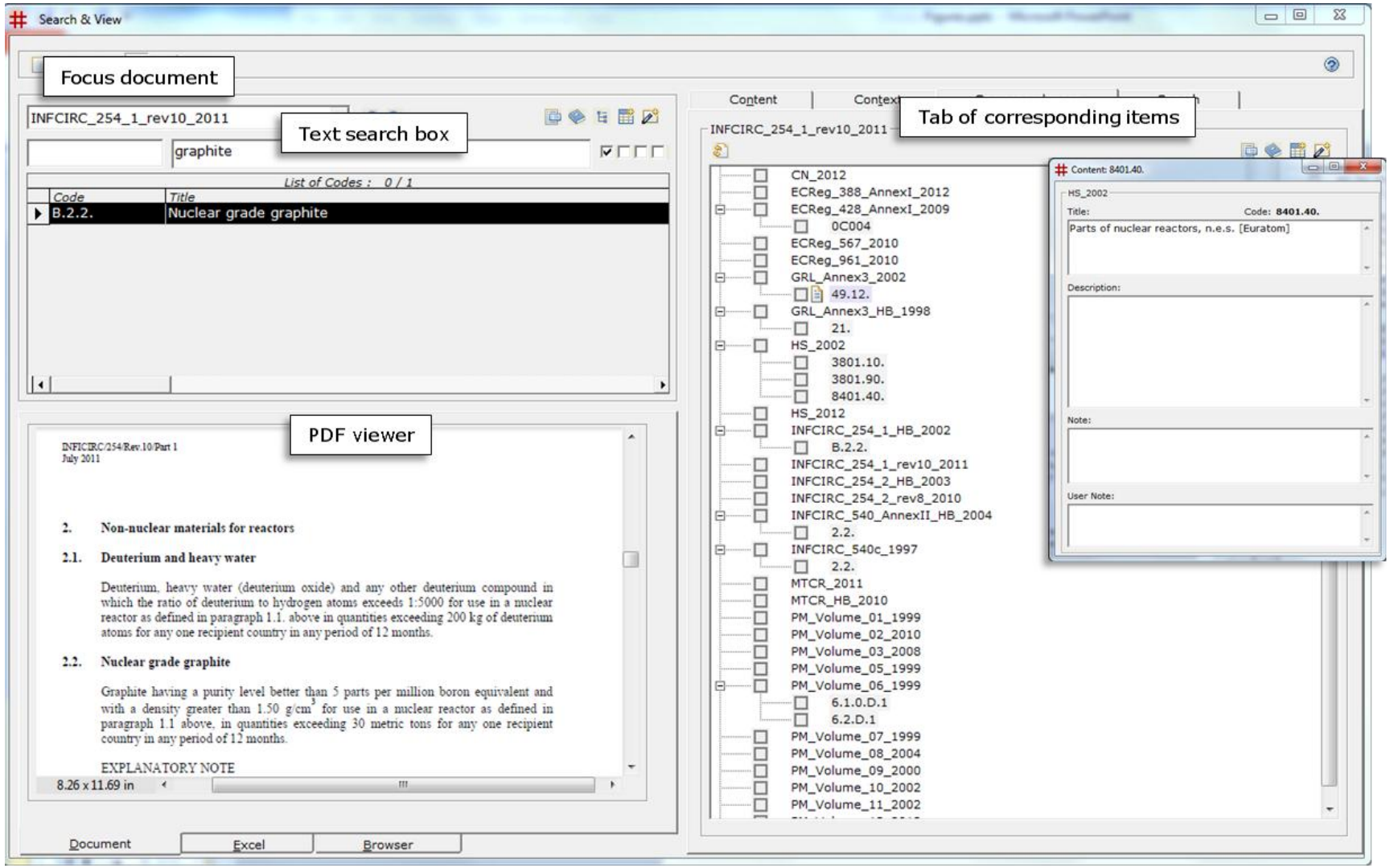

Figure 6 – The Big Table search interface.

4. The Physical Model in The Big Table format

Adding a document to the TBT collection requires storing it in database records of the type described in Section 3.1. The second step is to link the document to others in the TBT collection by correspondence tables as appropriate.

4.1. Coding the Physical Model in document tables

The IAEA has first run the exercise of turning the Volumes of the Physical Model into a database table. The table comprises about 3000 records. JRC has then proposed and implemented a way of coding the database records to reflect the PM structure in TBT.

A separate TBT document table was set-up for each Volume of the PM. In this way a Volume can be searched separately from the others (and have more precise results returned). Multi-volume searches are possible in the TBT *Search Tab*.

Figure 7 to Figure 13 give the structure of the *Code* field for the PM Volumes in the TBT database. A document table is logically divided in two parts: one for the Volume main body text (Figure 7), one for the indicators tables at the end of the Volume (Figure 8). In both cases the coding of items copies the multi-level structure of the PM with *Technologies*, *Processes*, and *Narratives.* Up to the *Narrative* level, the alpha-numeric code used in TBT is the one used in the PM documents. Underneath *Narratives*, a numbering of items and indicators was introduced by their order of appearance in the PM documents. Indicators codes have a 'Z.' prefix which makes them listed *at the end* of the database document table as in the original PM document.

Figure 14 shows as an example of coding part of the document tree of Volume 3 as it appears in TBT's search interface (for comparison see Figure 2).

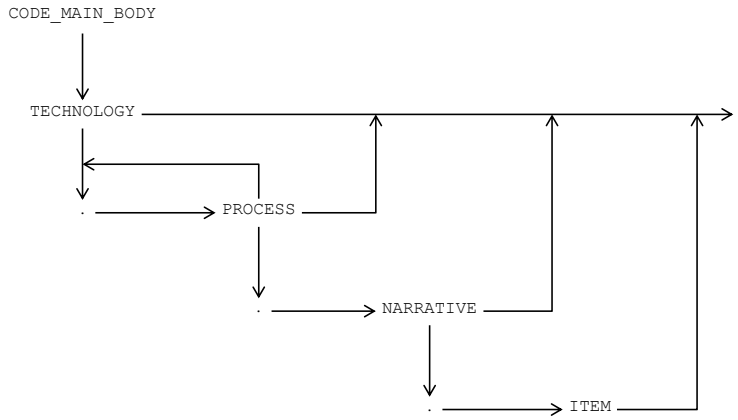

Figure 7 – Coding syntax for a Physical Model Volume main body text.

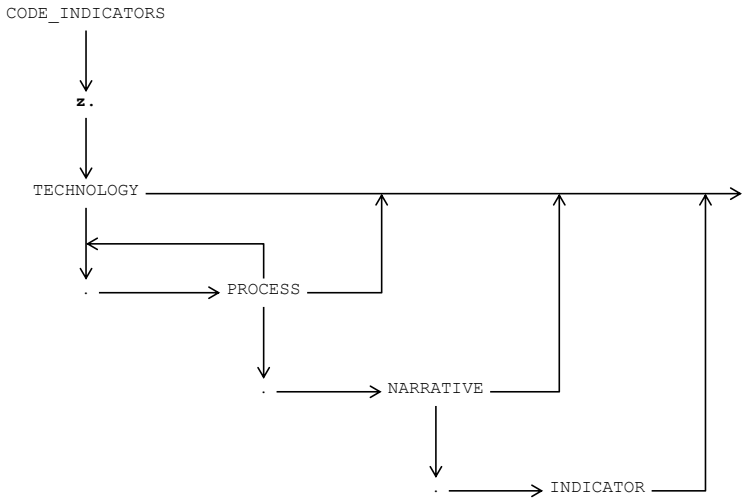

Figure 8 – Coding syntax for an indicators' table.

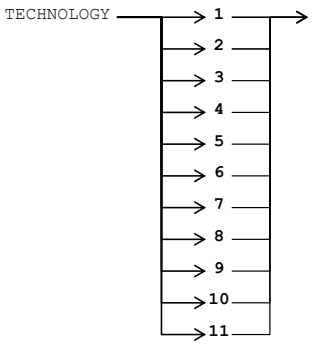

Figure 9 – Coding syntax for technologies. See also Table 1.

Figure 10 – Coding syntax for processes.

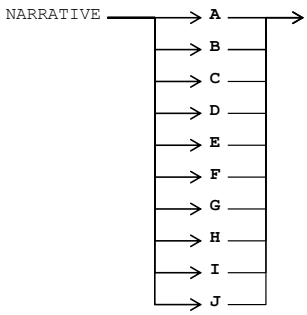

Figure 11 – Coding syntax for narratives. See also Table 2.

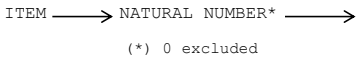

Figure 12 – Coding syntax for an item in the Physical Model.

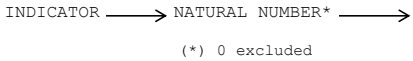

Figure 13 – Coding syntax for an indicator in the Physical Model.

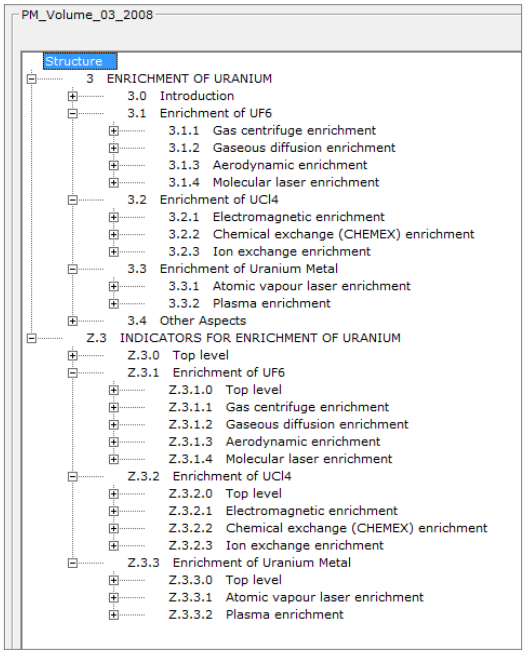

Figure 14 – Part of the TBT document tree for Volume 3.

4.2. Setting-up correspondence tables for the Physical Model

A first native correspondence for each Volume of the PM is one that relates its main body items and the indicators tables at the end of the Volume –a kind of self-correspondence. Having this correspondence implemented allows moving from an indicator in the tables *directly* to the items it refers to, and read these as PDF or database records.

Secondly, as mentioned in Section 2, seven PM Volumes make explicit reference to items listed in:

- INFCIRC 254 1 (or INFCIRC 540c)
- INFCIRC 254 2

These references were collected in native correspondence tables between the PM Volumes and the related documents in the TBT collection.

Figure 15 shows the schema of native correspondences implemented in TBT in the nuclear-related part of the document collection for a generic PM Volume X. Arrows indicate a native correspondence between pairs of documents. The number close to arrows box indicates the number of entries in a correspondence table.

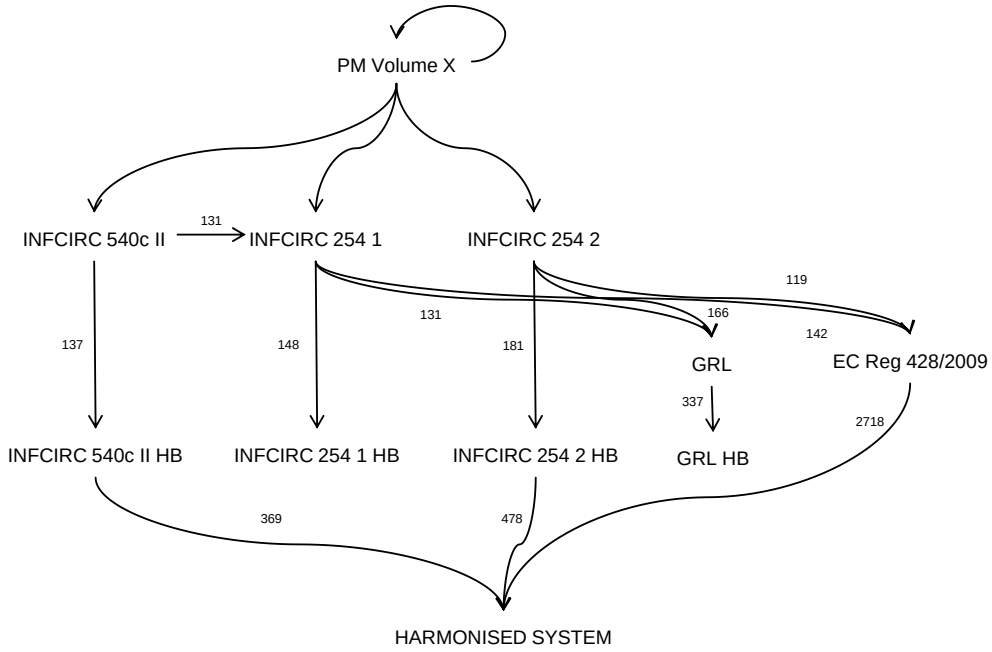

Figure 15 – Schema of native correspondences implemented in TBT's nuclear document collection. For the extended document reference see Table 3.

Native correspondences can be joined to derive new correspondences between a PM Volume X and other documents in the collection. For example, one can chain the two native correspondences:

- PM Volume X → INFCIRC 254 1
- INFCIRC 254 1 → INFCIRC 254 1 HB

to derive a new one:

- PM Volume X → INFCIRC 254 1 HB

In this way, handbook information about export-controlled items listed under the NSG list Part 1 is made directly accessible from a PM Volume (and viceversa).

Figure 16 shows the most complete possible set of native and derived correspondences between a generic PM Volume X and the other nuclear-related TBT documents, the sequence of derivation (D1 – D11) being presented in Table 5. It is used for all PM Volumes (3 Volumes in total) making reference to INFCIRC 254 1 (or INFCIRC 540c) and INFCIRC 254 2.

For those 4 Volumes making reference only to INFCIRC 254 1 (or INFCIRC 540c), the links to INFCIRC 254 2 and INFCIRC 254 2 HB do not exist.

For the remaining 5 Volumes, only the self-correspondence exists linking the items to the indicators in a Volume.

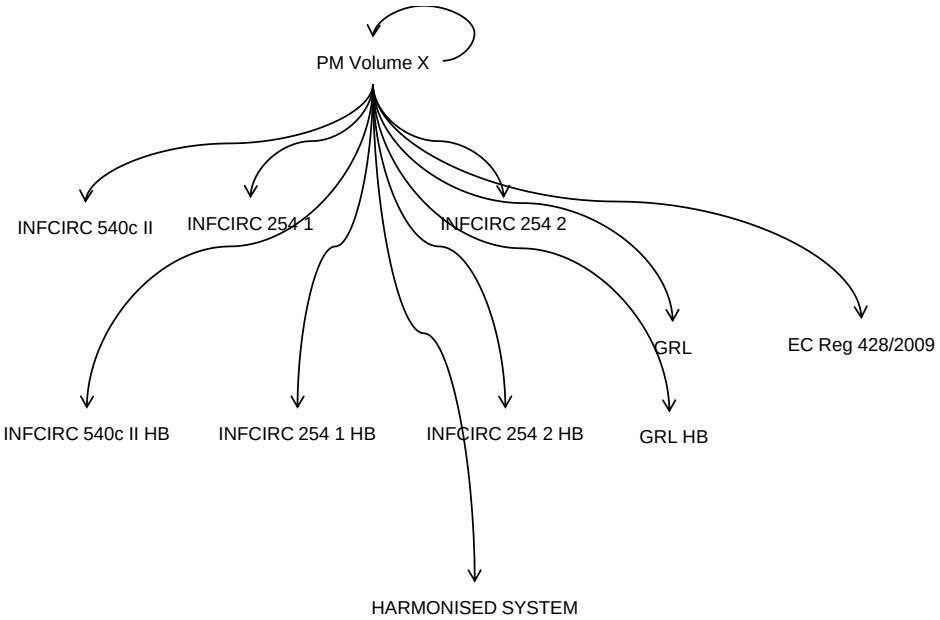

Figure 16 – Schema of native and derived correspondences for a generic Physical Model Volume. For the extended document reference see Table 3.

ID	Physical Model derived correspondences
D1	PM Volume X → INFCIRC 254 I → GRL
D2	PM Volume X → INFCIRC 254 II → GRL (merged with D1)
D3	PM Volume X → INFCIRC 254 I → EC Reg 428/2009
D4	PM Volume X → INFCIRC 254 II → EC Reg 428/2009 (merged with D3)
D5	PM Volume X → INFCIRC 540c II → INFCIRC 540 II HB
D6	PM Volume X → INFCIRC 254 I → INFCIRC 254 I HB
D7	PM Volume X → INFCIRC 254 II → INFCIRC 254 II HB
D8	PM Volume X → GRL → GRL HB
D9	PM Volume X → INFCIRC 540 II HB → HARMONIZED SYSTEM
D10	PM Volume X → INFCIRC 254 II HB → HARMONIZED SYSTEM (merged with D9)
D11	PM Volume X → EC Reg 428/2009 → HARMONIZED SYSTEM (merged with D10)

Table 5 – Sequence of correspondences derivation for a generic Physical Model Volume X.

4.3. The Physical Model Volumes integrated in The Big Table

The PM coding scheme presented in Section 4.1 was applied first to two sample PM Volumes for demonstration and comments by the IAEA. Specifically it was applied to Volume 3 (Enrichment of Uranium) and Volume 6 (Nuclear Reactors). Following a presentation of the result to the IAEA (May 2012), the integration was extended to all other PM Volumes with the exception of Volume 12.

Table 6 shows the total number of records per table, and how they split between items and indicators.

Table 7 shows the tables of correspondences, native or derived, for the PM Volumes in TBT. A cell gives the number of entries in the table. Numbers are type faced bold for native correspondences.

Volume	Title	References	Nr of DB records
1	Mining & Milling	-	• *339 total* • 171 items • 168 indicators
2	Conversion 1 and 2	• NSG2	• *778 total* • 437 items • 341 indicators
3	Enrichment of Uranium	• AP • NSG 2	• *797 total* • 236 items, • 561 indicators
5	Fuel Fabrication	• NSG 1	• *184 total* • 51 items • 133 indicators
6	Nuclear Reactors	• NSG 1 • NSG 2	• *700 total* • 346 items • 354 indicators
7	Deuterium/Heavy Water Production	• NSG 1	• *159 total* • 79 items • 80 indicators
8	Reprocessing of Irradiated Fuel	• NSG 1 • NSG 2	• *204 total* • 109 items • 95 indicators
9	Spent Fuel Management	-	• *231 total* • 111 items • 120 indicators
10	Radioactive Waste Management	-	• *271 total* • 133 items • 138 indicators
11	Hot Cell Operations at Nuclear R&D Centers	-	• *360 total* • 135 items • 225 indicators

Table 6 – TBT document tables for PM Volumes. See also Table 1.

		PM Vol 1	PM Vol 2	PM Vol 3	PM Vol 5	PM Vol 6	PM Vol 7	PM Vol 8	PM Vol 9	PM Vol 10	PM Vol 11
Mining & Milling	PM Vol 1	**105**									
Conversion 1 and 2	PM Vol 2		**271**								
Enrichment of Uranium	PM Vol 3			**507**							
Fuel Fabrication	PM Vol 5				**99**						
Nuclear Reactors	PM Vol 6					**296**					
Deuterium/Heavy Water Production	PM Vol 7						**31**				
Reprocessing of Irradiated Fuel	PM Vol 8							**92**			
Spent Fuel Management	PM Vol 9								**93**		
Radioactive Waste Management	PM Vol 10									**116**	
Hot Cell Operations at Nuclear R&D Centers	PM Vol 11										**183**
	EC Reg 428/2009		25	75	6	33	8	2			
	Harmonized System		58	380	48	172	14	18			
	INFCIRC 540c II			**68**	12	28	8	2			
	INFCIRC 540 HB			68	6	28	8	2			
	INFCIRC 254 1			68	**6**	**29**	**8**	**2**			
	INFCIRC 254 1 HB			67	6	29	8	2			
	INFCIRC 254 2		**32**	**30**		**4**		**3**			
	INFCIRC 254 2 HB		32	30		4		2			
	GRL		29	95	6	33	8	5			
	GRL HB		25	88	18	32	8	5			

Table 7 – Size of tables of correspondences in TBT for Volumes of the Physical Model. Native correspondences are indicated by bold numbers, the remaining are derived.

5. Open issues and future work

'The Physical Model provides a disciplined approach to defining what information should be collected and how it is most appropriately structured for analysis' [1].

Besides being a comprehensive set of documents on the Acquisition Path, the Physical Model was originally conceived to be a reference framework for IAEA analysts to collect information about States' nuclear activities in support to their evaluation [1].

Coding the Physical Model in a database format provides (part of) the information technology infrastructure useful to relate the PM to open source data and information of relevance to the IAEA' safeguards verification activities. An example (at the origin of The Big Table development) is the link between nuclear-relevant materials and equipment and global trade data as declared by exporters and importers to customs authorities. The origin of the data is independent from safeguards-related data declared by States to the IAEA, e.g. under Additional Protocols. Trade data can then be taken into consideration by the IAEA to verify State-declared information. The trade data, shared in global databases (e.g., COMTRADE and others [6]), are organised by the Harmonized System taxonomy of goods. *The integration of the Physical Model in The Big Table, enables to relate HS trade data to categories of the PM for 'reading' the data collected in the framework of the PM.*

An analogous approach is being pursued by the JRC in developing a trade flows tool for the analysis of INTRA- and EXTRA-EU exports of dual-use items [27]. There the reference framework for the collected trade data is the EU Regulation for export controls [10][16][17] and its categorisation of about 2000 items listed for controls.

Some issues remain open in the project of integrating the Physical Model with The Big Table.

A first relates to the way the PM Volumes are linked to the NSG documents in the TBT database. We included in the correspondence tables only the explicit references to the NGS lists already mentioned in the PM Volumes. However it looks like more references could be made to the NSG that are not identified in the PM Volumes. A revision of these correspondences by the IAEA is therefore recommended for completeness.

A second issue relates to the way the PM Volumes are linked to documents in the TBT collection other than the NSG documents. As explained in Section 4.2, the PM is linked to the other TBT documents *through* the NSG documents: the derivation of new correspondences start from there (Table 5). However there could be more links identified if a direct comparison is made between the PM Volumes and other documents in the TBT collection, such as the GRL or the MCTR lists of items. This issue has not been explored in the context of the work described in this report.

A third issue concerns the linking of manufacturing activities specified in Annex I of the Additional Protocol [3] with manufactured items listed in Annex II to the AP, and NSG 2 (dual-use) items associated with Annex I activities. Preliminary work in this direction is described in [28]. A natural extension to this work would be to create explicit connections between Annex I activities and the PM Volumes.

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Appendix:	**Acronyms**
AG	Australia Group [21]
AP	Additional Protocol
CWC	Chemical Weapons Convention [22]
DU	Dual-Use
HS	Harmonized System [7]
GRL	Goods Review List [14]
MTCR	Missile Technology Control Regime [19]
NSG	Nuclear Suppliers Group [20]
PM	Physical Model [1]
TBT	The Big Table [2]
WA	Wassenaar Arrangement [18]
WCO	World Customs Organisation [7]

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Integrating IAEA's Physical Model with The Big Table document search tool

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Abstract

The Physical Model (PM) is an internal multi-Volume document for the IAEA's Department of Safeguards on the nuclear fuel cycle. This report describes work carried out by the JRC with the IAEA to prototype the integration of the PM with The Big Table (TBT), a document search tool developed by the JRC and in use at the IAEA.

The core of TBT is an integrated collection of reference documents including regulatory documents, technical handbooks and trade nomenclatures. The documents are stored in a database. They are searchable by text in a structured way (i.e. on database fields) and also by correspondence tables that relate items by their meaning.

To integrate the Physical Model into TBT, the IAEA/SG/SGIM has first turned the PM into a tabular format. JRC has then proposed and implemented a way of coding the PM in TBT tables to better reflect the PM structure. Eleven PM Volumes have been integrated in a TBT-PM database for use by the IAEA. The PM Volumes are linked by correspondence tables to other documents in the TBT collection.

By coding the Physical Model into a TBT database format the original intended uses of the PM are still supported. TBT can ease the consultation of the PM for evaluating States' nuclear activities by IAEA's analysts. TBT can be an aid for IAEA's inspectors preparing for routine and ad hoc inspections, design information verification visits and complementary access operations. Further the PM integrated into TBT can be used as a tool for training inspectors on steps of the nuclear fuel cycle.

Finally implementing the Physical Model multi-level structure into a database-coded format opens the possibility of linking the PM to other taxonomies and collections of open sources relevant to safeguards analyses.

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